A Prototype Model of Household Activity/Travel Scheduling

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ABSTRACT

This paper presents the Toronto Area Scheduling model for Household Agents (TASHA). This new, prototype activity scheduling microsimulation model generates activity schedules and travel patterns for a twenty-four hour typical weekday for all persons in a household. The prototype model is based solely on conventional trip diary data, and therefore is applicable in many urban areas where activity data may not be available. The model makes use of the concept of the project, a "container" of activities with a common goal, to organize activity episodes into the schedules of persons in a household. A heuristic, or rule-based method is used to organize activities into projects, and then to form schedules for interacting household members. The TASHA model is considered to be a successful first attempt to operationalize a generalized conceptual model of household decision-making, with reasonable correspondence between model and observed trip rates and chain characteristics.

INTRODUCTION

It is only recently that operational models of the household activity scheduling process have begun to emerge. These models share a desire to replicate the sequence of decisions that leads to observed patterns of human activities and travel - including the decision of what activities to conduct, by whom, for how long, at what time and location, and by what mode. Doherty, *et al.* (*1*), and Arentze and Timmermans (*2*), among others, provide more extended discussions of the rationale for activity scheduling models and detailed reviews of the current state of the art in this area.

This paper presents a new, prototype activity scheduling model which generates activity schedules and travel patterns for a twenty-four hour typical weekday for all persons in a household. It is a microsimulation model in which the behavior of every household in a representative sample of households for an urban region is individually simulated. This model has been developed to meet several objectives, including:

1. It represents the first, simplified implementation of a much more comprehensive conceptual model of household decision-making presented in (*3*). It is hoped that this conceptual model will eventually provide the basis for the unified modeling of both long-run (housing location, auto ownership, etc.) and short-run (activity/travel) decisions of households and their members within an integrated transportation – land use modeling system.
2. Due to lack of an activity-based survey for the study area, the model is developed using a conventional trip-based travel survey. The modeling exercise thus represents a test of the suitability of conventional trip-based survey data as proxies for out-of-home activity data in the construction of an activity-based travel model. To the extent that this proves to be a feasible proposition, it opens the possibility for other urban areas to build improved travel demand models in cases where an activity-based survey cannot be undertaken for one reason or another.
3. It demonstrates the feasibility and practicality of activity-based microsimulation modeling of twenty-four travel in a large urban area for operational policy planning purposes.

This paper begins with an overview of the conceptual framework for household decision-making. The paper then describes a prototype activity scheduling model with household agents which has been recently developed for the Toronto region. The paper concludes with a brief discussion of future work required to evolve the current prototype into a model that is more complete in its implementation of the conceptual framework and, at the same time, is fully operational for transportation planning and policy analysis.

PROJECTS AND ACTIVITY SCHEDULING

Axhausen (*4*) defines a **project** as a coordinated set of activities tied together by a common goal or outcome. A simple example of a project might be a dinner party, for which individual (but inter-connected) activities might include: planning the party, shopping for food and drink, preparing the meal, cleaning the house, and the actual dinner party. Projects can spawn sub-projects if the sub-project is sufficiently important and coherent in terms of having a definable objective in its own right.

In addition to its type, two key attributes of a project are the **project task list** and the **project agenda.**

The project agenda is a list of specific activity episodes that are actively being considered for insertion into the current planning period's schedule. **Activity episodes** are specific occurances of an activity. They are explicit objects which only persist within the model until they have been scheduled and executed. They are primarily defined by their **attributes** (which, at a minimum, consist of start time, duration and location) and possess little behavior *per se*. If the simulation model were to be run over a sequence of planning periods, then the agenda's contents (i.e., the set of episodes) would vary over time as current episodes are scheduled and deleted and as new episodes are added by the project to the list.

The project task list, on the other hand, is persistent throughout the life of the project. Its elements are activities in which the person **might** engage at some point in the project, but may not necessarily do so within the current planning period. Activities are also objects, but they possess little in the way of attributes and are primarily defined in terms of their **behavior**. That is, an activity possesses the information and the methods needed to generate specific instances of activity episodes. Thus, the "knowledge" about how activity episodes are generated (how often, constraints on duration, etc.) are contained within the activity.

Scheduling can go on "within" a project, provisionally ignoring other projects/parts of a person's schedule. For example, one may schedule one's "work week" largely independently of home-based activities. This within-project scheduling can be **encapsulated** within the project, both in terms of the scheduling act and in terms of many of the details of the resulting project plan.

Projects involving commitments to other persons/agents tend to be generally more binding/compelling than commitments made only to one self, for at least two reasons. First, the commitment ("contract") means that the other agent(s) involved are counting on the person to fulfill the commitment. Second, the successful execution of the project often requires agreement on the allocation/sharing of resources (e.g., who gets the car) and/or cooperation in a joint venture. This is presumably why projects like work and school (which involve considerable collaboration and committing to contracts for delivery of services) are viewed in most activity models as "mandatory" or "priority" activities.

Note that within this framework travel is not a project. Rather, it is an activity that is spawned by any episode which requires the person to move to a new location in order to participate in the given episode. A travel episode (i.e. trip) is a specific instance of the travel activity. As with any episode, a travel episode has a start time, duration (travel time) and location (in this case defined by two points – the trip origin and destination). In addition, a travel episode has a mode and, ultimately, a route.

Many approaches to modeling activity scheduling are no doubt conceivable. In this paper, the following hypotheses are maintained and provide a basis for model operationalization:

First, a fundamental assumption is that **scheduling is an event-driven, sequential process**, in which individual episodes are provisionally scheduled as they "arise" out of the personal and household projects. That is, at any point in the scheduling process, a partial, provisional (but feasible) schedule exists. When a new episode is "presented" to be scheduled, it is, along with any modifications to the prior provisional schedule required to accommodate the newly inserted episode.

Given this, it follows that, in general, **activity/travel scheduling is not an optimizing procedure**. The sequential insertion process briefly described above tends to be myopic and greedy, and therefore may well result in a final schedule which is "sub-optimal" with respect to a given set of criteria. In particular, modifications to an existing, provisional schedule tend to be "local" in nature. That is, the person will only rearrange his/her schedule to a certain degree to accommodate a new episode. Over and above practical concerns about computational intensity, etc., this is fundamentally a behavioural argument, which has at least two components. First, as in all aspects of life, it simply isn't clear that people are generally "global optimizers". Second, in the case of activity scheduling, so many activities come with sufficient constraints (start/stop times, fixed locations, etc.) and/or commitments with others that the "degrees of freedom" available for significant (re-)optimization of an entire schedule are likely to be very minimal.

A third fundamental assumption is that travel mode choice (and the associated allocation of household vehicles for individual person travel, as required) is inherent in the activity scheduling process. That is, **travel episodes must be (provisionally) scheduled along with their associated activity episodes**, since activity episode timing and feasibility can not, in general, be determined independent of the travel episodes required to get to and from the activity.

THE TORONTO AREA SCHEDULING MODEL WITH HOUSEHOLD AGENTS (TASHA)

General Description of the Operational Model

As a first step in implementing the conceptual model sketched in the previous section, a prototype microsimulation model of the activity scheduling process has been developed for the Greater Toronto Area (GTA). The Toronto Area Scheduling model with Household Agents (TASHA) is currently operational and is based on trip diary data from the 1996 Transportation Tomorrow Survey. The scheduling model microsimulates a 24-hour schedule formation process for residents of the GTA. The major features of the operational model are as follows:

The model makes use of the concept of the project to organize activity episodes into the schedules of persons in a household. As discussed in detail in the previous section, projects are the "containers" within which activity episodes are generated.

The model features interactive household agents. The schedules of the persons within the household are generated simultaneously to allow for interaction between members that normally occurs within a household. The key way that household members interact in the current model is through the generation of joint activity episodes in which more than one person in the household takes part in an activity. Joint activities require that the activity occurs with the same start time, duration and location for each participant. Therefore a "window" of opportunity must exist or be created in the schedules of all of the household members taking part in that activity for it to be a feasible joint activity. There are many other ways in which household members interact to "coordinate" their schedules. Obvious examples of household interaction that are reserved for future versions of the model include household vehicle sharing, and the coordination necessary for the care of children.

The model is a microsimulation of a 5% sample of households in the Greater Toronto Area. A total of approximately 89,000 households and 243,000 persons are represented as individual entities in the computer model. Activity/travel schedules are generated for each person individually.

The model was designed using an object oriented programming technique. Object orientation is a modelling paradigm that attempts to mirror real life objects relevant to the scheduling process directly as "classes" in the program code. The class design for TASHA is shown in Figure 1. In this figure, households, persons, projects, activity episodes and travel episodes are each represented as explicit model entities. Each household has persons, and each person has a schedule which contains all activity episodes and travel undertaken by that person. Both households and persons have projects, each of which has an agenda consisting of all activity episodes relevant to that project. The model also contains a spatial representation of the GTA, as well as a series of probability distributions for activity episode frequency, start time and duration.

The model assumes broad project and episode types. Projects are assigned as either person-level or as household-level projects. Broad project types are assigned to each household and to each person as shown in Figure 2. While a more detailed definition of projects would be advantageous, the travel survey data used to develop the model did not provide a finer level of activity type ("trip purpose") detail than that shown in Figure 2. The serve-dependent household-level project has not been incorporated into the current prototype model. It does, however, represent an important point of interaction among household agents (i.e. adults must coordinate with each other over the care of their children), and will be incorporated into the next version of the model.

Within each project, one or more episodes types are incorporated. The work project is the most complex project as it houses several activity episode types. These episode types include:

- *Primary work* – work episodes occurring at the usual place of work that are part of the primary work event. The primary work event is defined as the sequence of work episodes beginning with the first work episode of the day plus any work episodes from subsequent work chains that begin before 3:00 p.m.,
- *Secondary work* – work episodes occurring at the usual place of work that are part of the secondary work event. The secondary work event is defined as the a sequence of work episodes in a chain that starts after 3:00 p.m., given that a primary work event has occurred,
- *Work business* – work episodes that occur at a location other than the usual place of work, for a person that normally works at a location other than their home,
- *Work-at-home business* - work episodes that occur at a location other than home, for a person that normally works at home, and
- *Return home from work* – at-home episodes that are embedded within the primary work event. These episodes can be thought of as lunch trips but may include other at-home activities.

Each of the other projects currently contains only a single episode type, which is of the same name as the project.

The model assumes household decisions other than activity scheduling are made exogenously. Household members make decisions simultaneously on many different aspects of their lives. Mode choice, for example, is strongly integrated with decisions about where and when to undertake activities, and choice of residence and work location are longer run decisions that influence and are influenced by activity choices. In the current model, however, other major household decisions, including residence location, work location and auto ownership, are assumed to be made exogenously . Mode choice is also handled separately from the activity scheduling model as follows. First, auto drive travel times are assumed in the schedule formation procedure to determine how much time must be allocated for travel in a person's schedule. Travel mode choices are then determined once the schedule has been constructed using a newly developed trip-chain-based mode choice model.

Base Data

An activity-based survey for the GTA is not currently available. Given this, TASHA is based on trip diary data from the 1996 Transportation Tomorrow Survey (TTS). The TTS is a traditional household-based trip diary survey in which attributes of the household, of all household members, and of all weekday trips made by household members over a 24-hour time period are collected.

The 1996 TTS data are used for the generation of activity schedules in two ways. First, the database provides the base population on which the schedule model is run. Attributes of the households (e.g. number of vehicles, residence location) and person attributes (e.g. age, sex, employment status) are considered to be exogenous inputs into the scheduling model.

Second, TTS trip data are used for generating activity episode attributes including their frequency, start times, durations and the number of people involved. Given the large survey sample size (5%), these distributions can be constructed with a high degree of confidence. Some manipulation is necessary to extract activity attributes from the trip database. Activity durations, for example, are determined by comparing the start times of two consecutive trips and subtracting an estimated travel time for the first trip.

The Prototype Scheduling Model

In the current model version, person schedules are constructed "from scratch" based on the following steps:

- Activity episodes are generated for insertion into each project agenda based on 1996 TTS distributions of activity attributes.
- These activity episodes are inserted into project agendas where they are placed into a preliminary time sequence with other activity episodes that are connected by a common purpose.
- Once the project agendas have been formed, person schedules are constructed by taking activity episodes from the project agendas and adding them to the person schedule. Activity attributes are modified and travel is added as necessary to result in a coherent consistent schedule.

- A "clean up" algorithm is applied to reflect final scheduling / fine tuning just before or during execution of the schedule.

As such, the procedure is an event-driven "bottom-up" approach to activity scheduling, which is in contrast to the "top-down" approach used in a variety of other scheduling models in which "patterns of activities" are chosen from a large, but finite set of observed activity patterns (*5, 6, 7*). It is felt that the "bottom-up approach" is more conducive to dynamic scheduling in which schedules are constantly changing due to new opportunities and constraints that a person encounters prior to the execution of their schedule.

The procedure for generating schedules for members of a household and the underlying assumptions for each of the schedule formation steps are outlined below. Further documentation of the model assumptions can be found in (*8*).

Activity Episodes are Generated for Insertion into Each Project Agenda. At the outset, the project agenda is blank for each project. Activity episodes are then generated based on 1996 TTS probability distributions for frequency, start time and duration along with reasonable rules to ensure that the resulting agendas are logical.

The generation of activity episodes for the work project is particularly complex given the number of activity types that are included in this project. In general, the following principles are adhered to when generating work project episodes.

- Episodes are generated and inserted in the following order: primary work episode, work business episodes for people with a usual place of work, secondary work episodes, return home from work, work business for people with no usual place of work, work-at-home business.
- Frequency of episodes of each type is randomly chosen from the appropriate marginal frequency distribution for that person/episode type, as shown in Figure 3a.
- Given the frequency, start time is then chosen randomly from the portion of the joint frequency-start time distribution where start times are feasible given the following set of logical rules (see Figure 3b):
    - Work business episodes fall within the primary work event
    - Secondary work episodes must start at least one hour after the end of the primary work event and after 3:00 p.m.
    - Return home from work (i.e. lunch) must conclude before 3:00 p.m. and must result in at least 30 minutes of work before and after the returning home. Return home from work episodes are not generated if the start time of the primary work event is later than 12:00 p.m.
- Given start time, duration is then chosen randomly from the feasible portion of the joint start time-duration distribution given the following constraints (see Figure 3c):
    - Work-business episodes must be less than the duration of the primary work event
    - Secondary work episodes must start at least one hour after the end of the primary work event and must conclude by the end of the day
    - Return home from work (i.e. lunch) episodes must be at least one hour less than the duration of the primary work event

- For primary work and return to work episodes for people with a usual place of work, the employment zone is assigned to the primary work episode. For all other episodes, other than the return home from work, location is randomly generated using a logit choice model based on 1996 TTS data.

For other person-level activity episodes, the generation of episodes is done simply by assessing the frequency, duration and start time from the appropriate probability distributions for that person/episode type. Episode locations are randomly chosen using a logit model that is sensitive to both home and work locations (see a description of the location choice model in *(9)*).

Activity episodes are inserted into person-level and household-level project agendas. Once activity episodes are generated, they are added to project agendas along with other activity episodes with a common purpose. Activity episodes are inserted into the appropriate project one by one such that each project is internally consistent, or in other words, there are no activities within a project agenda that overlap in time. As such, construction of the project agendas represents the first step that a person takes to begin to organize their desired activities into a preliminary sequence. A project agenda may contain "gaps" with no planned activities. It is also noted that a project agenda does not include travel, which is only accounted for when a person constructs their actual schedule.

There are four different cases that occur when a "new" activity episode is being inserted into a project agenda that already contains "existing", previously inserted activity episodes. The cases include splitting an episode (Case 1), inserting an episode between "prior" and "posterior" existing episodes (Cases 2 and 3) and overlapping an existing episode completely (Case 4). These cases are described in Figure 4.

The process of inserting episodes into project agendas involves the application of the following rules/assumptions.

- When the new episode being inserted overlaps with part of at least one existing activity episode, the following steps are followed to attempt to create an appropriately sized "gap" for the new activity.
    - If either of the prior or posterior existing episodes is a "gap" in the project agenda then the new episode is shifted to replace all or part of the "gap",
    - The prior episode is shifted if a "gap" exists in the project agenda immediately before the prior activity,
    - The posterior episode is shifted if a "gap" exists in the project agenda immediately after the posterior activity,
    - The durations of the new episode and the existing episodes are reduced in proportion to their durations to a minimum of 50% of their original duration,
    - If all of the above fail, the insertion is considered to be infeasible and the new episode is rejected.
- If activities are rejected due to scheduling conflicts, they are regenerated with a new randomly generated start time and duration up to a maximum of 10 attempts.

Person schedules are constructed by taking activity episodes from the project agendas and adding them to the person schedule. While projects are used to organize partially elaborated activities into sequence with other activities with a common purpose, the final timing of the activities must be coordinated with activities from other projects. The process of generating a person's schedule, therefore, involves taking episodes one-by-one from the project agendas and adding them to the person schedule in order of priority.

The order of priority is chosen to reflect to the greatest extent possible the degree of preplanning and commitment to other agents (such as employers or other household members). The order used in the current operational model is as follows:

- Work-business episodes,
- Primary work episodes,
- All other work episodes,
- School episodes
- Joint other episodes,
- Joint shopping episodes,
- Individual other episodes, and
- Individual shopping episodes.

The construction of the person schedule proceeds in a manner similar to that of the project agendas. The major differences are that in the person schedule, travel episodes are added to account for the time necessary for trips between activities with different locations, and that the person schedule does not include "gaps" or areas with no planned activities. It is noted that at the beginning of the scheduling process, a person's schedule consists of a single "at-home" activity, which is the default if no other activities are added to the schedule.

An example of an episode insertion into a person schedule is shown in Figure 5. As shown in this diagram, a number of steps are followed to insert an episode into a person schedule.

- The travel episode from episode 1 to episode 2 is deleted,
- New travel episodes are defined from existing episode 1 to the new episode and from the new episode to existing episode 2.
- Episodes 1 and 2 are shifted forward and backward, respectively, to allow for the necessary room to insert the new episode and the two new travel episodes.
- If "non-home" episodes exist directly before Episode 1 and directly after Episode 2, then there is assumed to be no room for shifting of episodes. In this case, episodes 1, 2 and the new episode are truncated in proportion to their durations to a maximum of a 50% reduction in duration.
- If all of the above steps are unsuccessful then the insertion is considered to be infeasible.

A "clean up" algorithm is applied to reflect final scheduling / fine tuning just before or during execution of the schedule. Once a preliminary 24-hour schedule is, further scheduling changes can be made to reflect decisions made just before or during the execution of a person's schedule. These may include cleanup or optimization algorithms, but also may allow for the introduction of random events, impulsive changes, and further modification, revisions, re-sorting and planning. At present, this stage of the scheduling process is limited to a single cleanup algorithm that is applied to rearrange the schedule to remove unrealistically short work episodes with duration less than or equal to a 30 minute duration.

INITIAL MODEL RESULTS

The prototype model replicates 1996 trip-making characteristics in the GTA reasonably well. Table 1 compares TASHA model trip totals to observed trip totals by time period, by trip destination purpose. It is noted that Table 1 compares model-generated results to the base TTS trip data rather than another data source such as cordon counts. By making this comparison as an initial validation exercise, it is possible to clearly assess the overall adequacy of the scheduling model rules, isolating them from inadequacies in the base data. The following observations are made based on results in this table.

- Overall, the model underestimates daily trips by approximately 311,000 trips (-3.3%).
- Total daily trips by destination purpose are slightly overestimated for work trips (1.7%) slightly underestimated for school trips (-1.7%) and home trips (-2.7%) and significantly underestimated for shopping (-10.0%) and other trips (-10.2%). The model underestimates trips, in general, because of scheduling conflicts that result in the rejection of activity episodes. Rejections occur more often for shopping and other activities because they are assumed to be lower priority activities that are scheduled last.
- Total trips in the PM Peak Period (3:00 p.m. to 6:59 p.m.) and the night time period (7:00 p.m. to 5:59 a.m.) are slightly over-estimated (2.4% and 2.9% respectively), whereas the trips in the AM Peak Period and the Midday Period are significantly underestimated (-12.1% and –8.3%, respectively). Underestimation of trips in the AM and Midday Periods is a result of scheduling conflicts that occur more often in these time periods. In the TASHA model, such scheduling conflicts result in a shift in trip start times out of the desired time period into adjacent time periods or in an outright rejection of conflicting activities.

In addition, the number trips per home-based chain is accurately modeled. The model predicts, on average, 2.18 trips per chain, while the TTS data indicates 2.19 trips per chain (calculated as the total number of trips divided by the number of trips destined for home). This is encouraging since trip chains are an “emergent” outcome of the modeled scheduling process.

Overall, the model replicates observed trip making within what are considered to be acceptable limits for a prototype model. However, there is significant room for refinement in the model as our understanding of activity scheduling rules improves, new data sources become available, and alternative assumptions about elements of scheduling such as mode choice, location choice, learning and habit formation are tested in the microsimulation framework. There also exists the need to further test the scheduling algorithm using schedule process data that are currently being collected in Toronto (see an example of the survey instrument in *(10)*).

Computationally, the TASHA model runs efficiently. In total, the model takes approximately 5.5 minutes to run on a Pentium 3 with a 1 GHz processor. For a total of 89,000 households this is a processing rate of approximately 270 simulated households per second, or

735 persons per second. A total of approximately 150 MB of RAM is required to run the software.

FUTURE RESEARCH

Two streams of further research are currently underway to further improve the behavioral basis for the TASHA model. First, improvements that can be made within the current modeling framework, based on currently available data, include:

- Improving the activity location choice model embedded within TASHA
- Incorporation of the mode choice model into the scheduling procedure
- Incorporation of additional joint household decisions such as the care of children and vehicle allocation

Second, a unique custom-designed computerized survey tool, entitled CHASE©, is currently being used in the Toronto Area to explicitly capture the dynamic scheduling process that household members engage in (*9*). Results from this survey will allow the following improvements to the model:

- Applying different strategies for scheduling to different people
- The movement from a 24 hour model to a week-long model
- A much more detailed representation of episodes and projects
- Scheduling of activity episodes that is based on observed information about those episodes regarding their priority, flexibility and when they were planned. This is in contrast to the rather ad hoc priority ratings currently being used in the prototype model.

CONCLUSIONS

The TASHA model is considered to be a successful first attempt to operationalize the conceptual model presented by Miller (*3*). Furthermore, the model is based on a conventional trip diary survey, meaning that the approach presented could be applied in most large metropolitan areas where such data exist. Reliance on trip data allows for a credible model to be developed, however, it does restrict further model development mainly because of the crude trip purpose categorization, the observation of only a 24 hour time period and a failure to explicitly capture the dynamic scheduling process a household engages in. Nonetheless, the current model shows that implementation is clearly feasible, computationally efficient, and provides a sound basis for further evolution of the model.

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TABLES

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TABLE 1 Comparison of Modeled to Observed Trips[1]

[1] table does not include "facilitate passenger" trips (giving rides), which are not modeled, or school trips for children under 11 years of age.

Trip DestinationType		Trip Comparison by Time Period (1,000's of trips)				Total Daily Trip Comparison
		AM Peak Period 6:00am–8:59am	Midday Period 9:00am-2:59pm	PM Peak Period 3:00pm-6:59pm	Night-time Period 7:00pm-5:00am	
Work	Modeled Trips	1187.1	651.9	223.6	222.6	2285.1
	Observed Trips	1366.0	533.7	193.7	153.7	2247.1
	Model +/- Trips	-179.0	118.3	29.9	68.9	38.0
	Model +/- %	-13.1%	22.2%	15.4%	44.8%	1.7%
School	Modeled Trips	533.3	102.9	20.7	8.8	665.8
	Observed Trips	551.5	99.5	22.3	3.9	677.2
	Model +/- Trips	-18.2	3.5	-1.5	4.9	-11.4
	Model +/- %	-3.3%	3.5%	-6.9%	123.3%	-1.7%
Shopping	Modeled Trips	25.7	287.3	287.6	112.5	713.1
	Observed Trips	15.6	411.3	247.4	118.5	792.8
	Model +/- Trips	10.1	-124.0	40.2	-6.0	-79.6
	Model +/- %	65.0%	-30.2%	16.3%	-5.0%	-10.0%
Other	Modeled Trips	86.3	365.7	473.1	333.3	1258.4
	Observed Trips	95.2	507.9	453.1	344.4	1400.6
	Model +/- Trips	-8.9	-142.3	20.0	-11.1	-142.3
	Model +/- %	-9.4%	-28.0%	4.4%	-3.2%	-10.2%
Home	Modeled Trips	27.3	645.4	2247.5	1251.5	4171.6
	Observed Trips	87.2	687.4	2259.8	1253.0	4287.3
	Model +/- Trips	-59.9	-42.0	-12.3	-1.5	-115.7
	Model +/- %	-68.7%	-6.1%	-0.5%	-0.1%	-2.7%
Total	Modeled Trips	1859.6	2053.2	3252.6	1928.7	9094.0
	Observed Trips	2115.5	2239.7	3176.2	1873.5	9405.0
	Model +/- Trips	-255.9	-186.6	76.3	55.1	-311.0
	Model +/- %	-12.1%	-8.3%	2.4%	2.9%	-3.3%

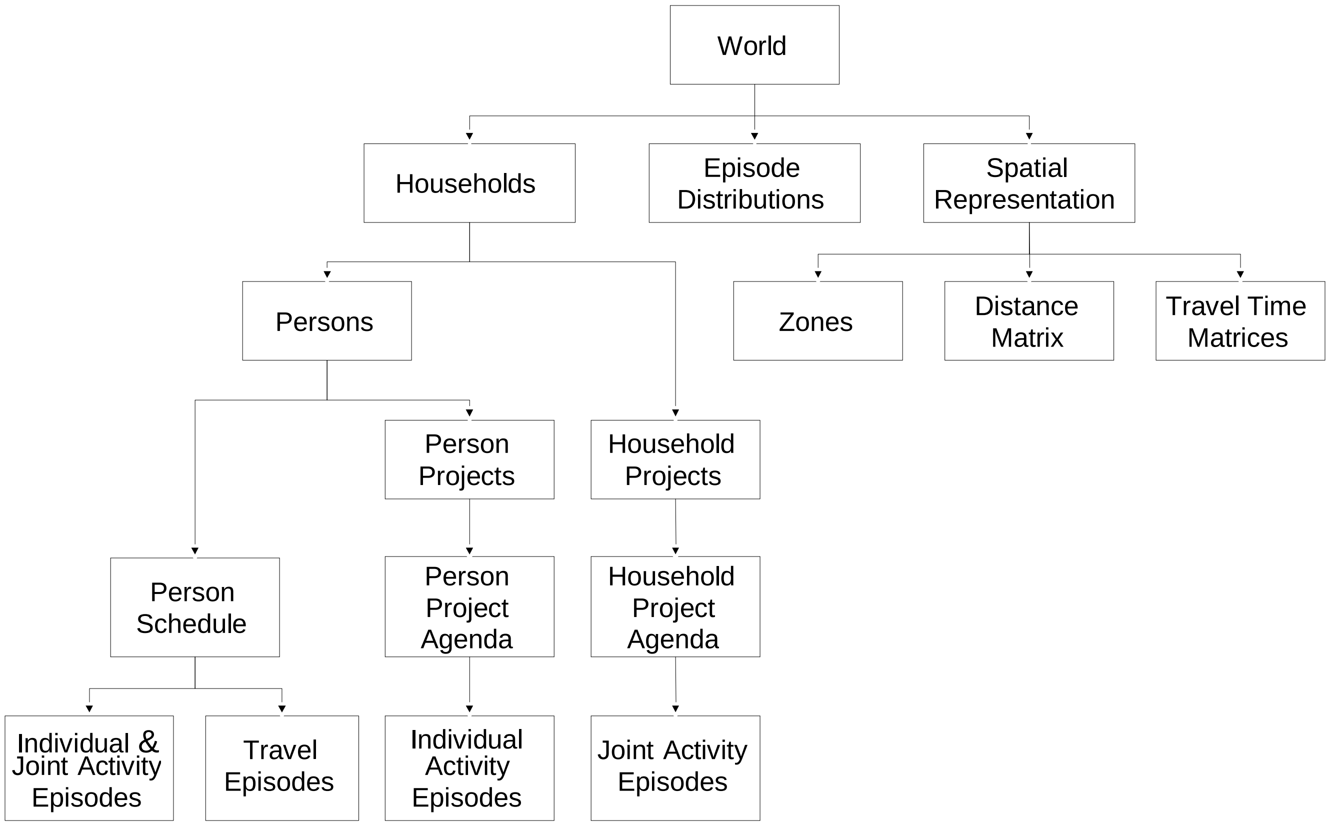


FIGURE 1 Object-oriented class structure.

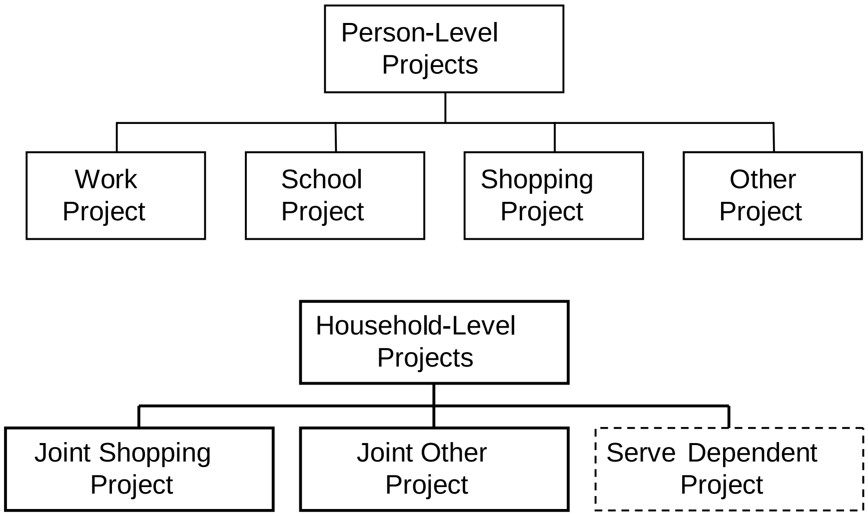


FIGURE 2 Project types.

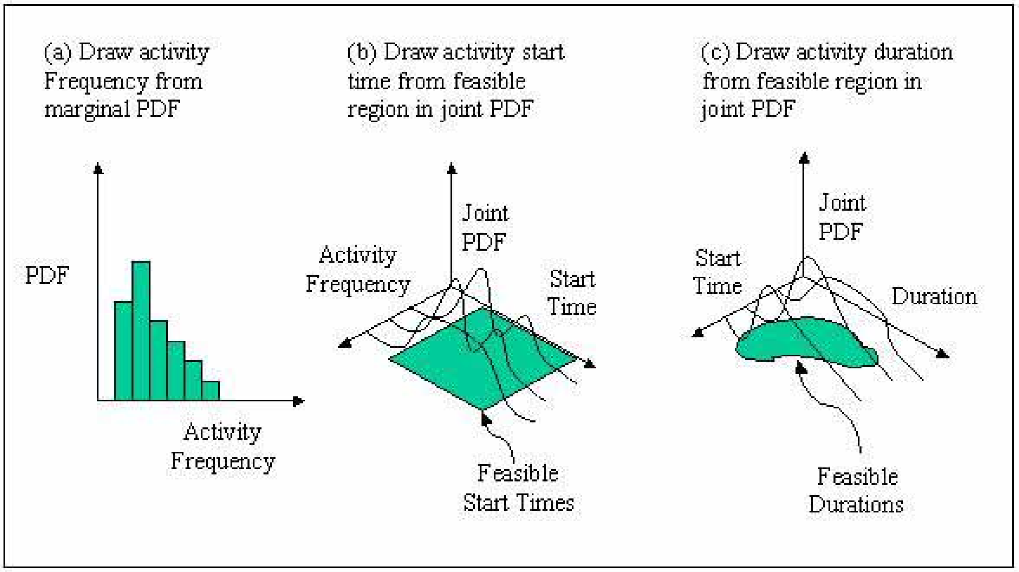
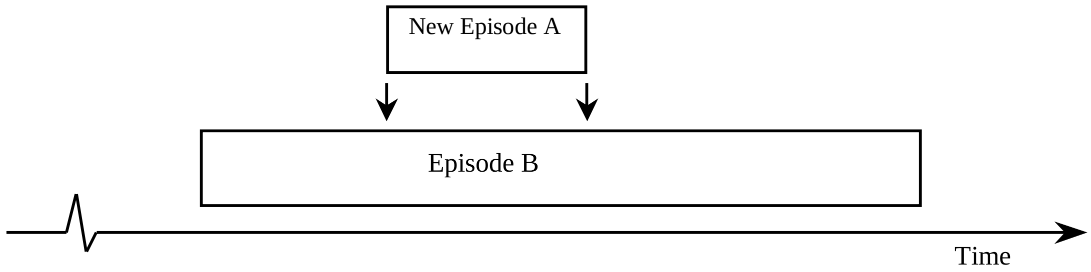
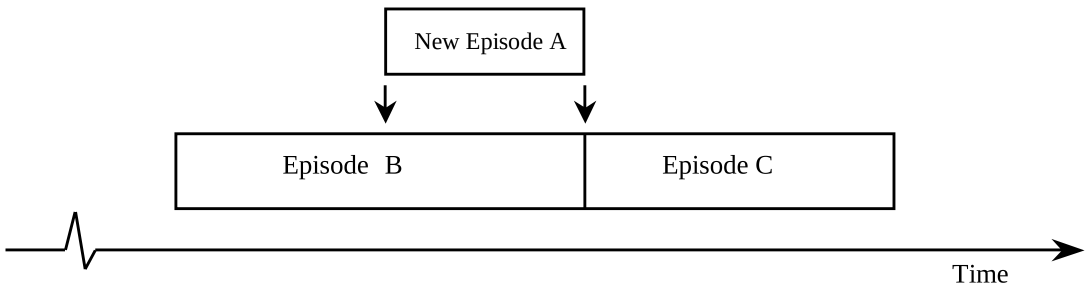


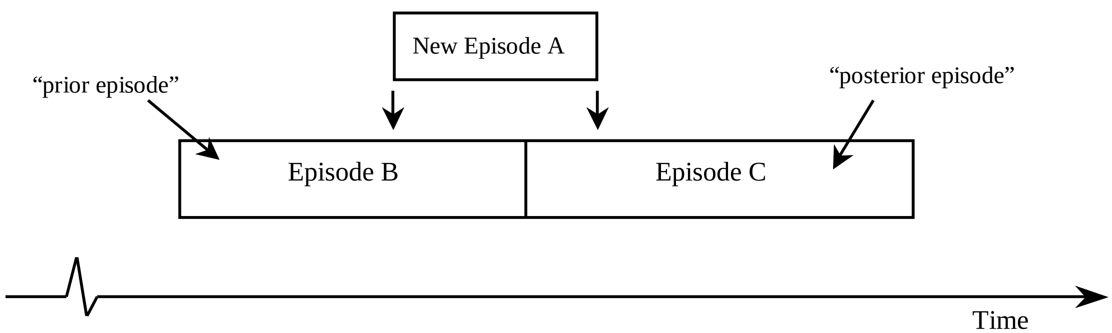
FIGURE 3 Activity episode frequency, start time and duration generation



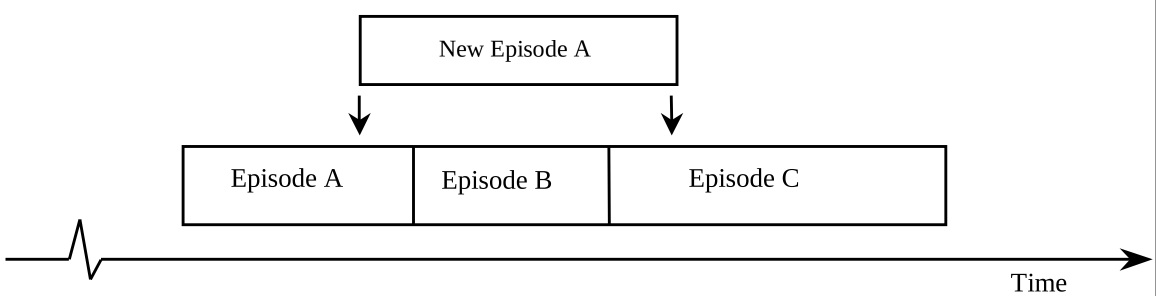
Case 1 – The new episode being added to the project agenda is added **within** an existing episode, thereby splitting it into two episodes. This type of insertion is only allowed in the work project agenda, where the episode being split is the primary work event.



Case 2 – The new episode being added to the project agenda can be inserted **between** two existing episodes, but the new episode only overlaps one of the episodes because the new episodes end (or start) time coincides with one of the existing episodes' end (or start) time.



Case 3 – The new episode being added can be inserted between two existing episodes. However, the start and end times of the new episode do not coincide with either of the existing start or end times so the new episode overlaps both existing episodes.



Case 4 – A long duration activity might completely overlap one or more shorter episodes. This case is disallowed. In the current model, the new long duration activity episode would be rejected from the project agenda.

FIGURE 4 Inserting activity episodes into project agendas.

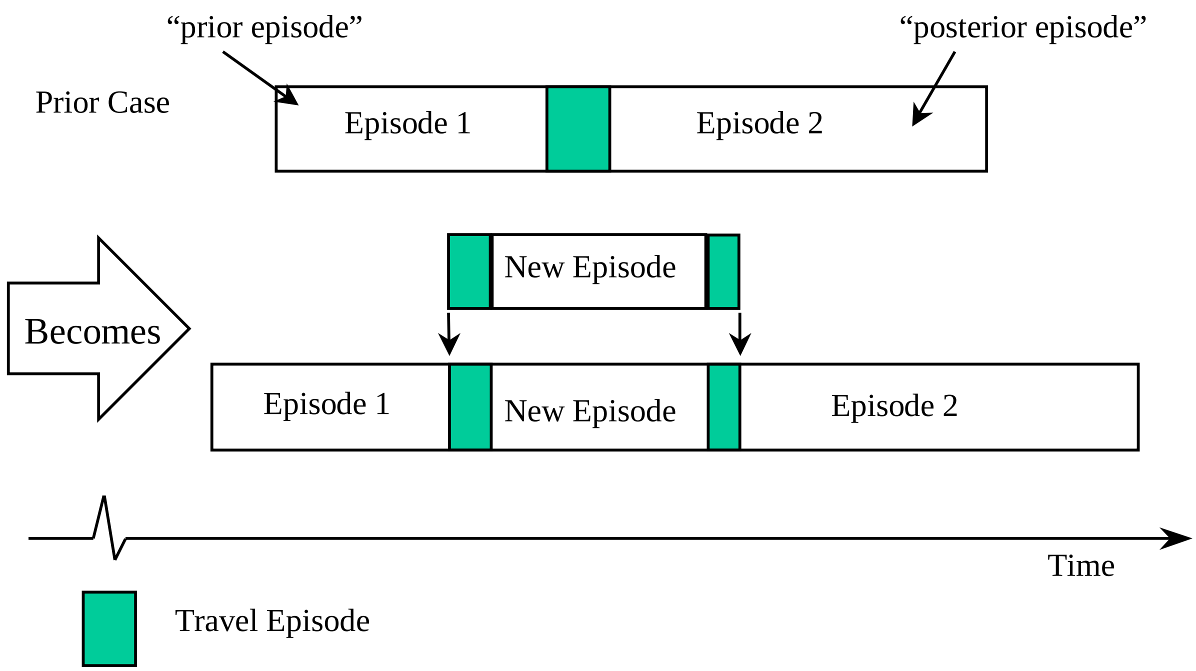


FIGURE 5 Inserting an activity into a person schedule with travel.